Time-Limited Subsidies:

Optimal Taxation with Implications for Renewable Energy Subsidies

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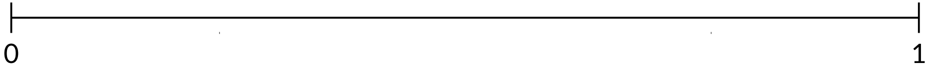
  - Application: The Renewable Electricity Production Tax Credit (PTC) for wind energy

Intuition from a simple two-period model



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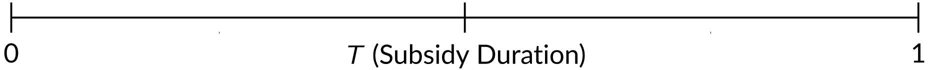

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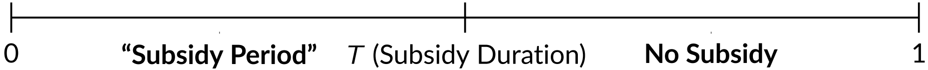

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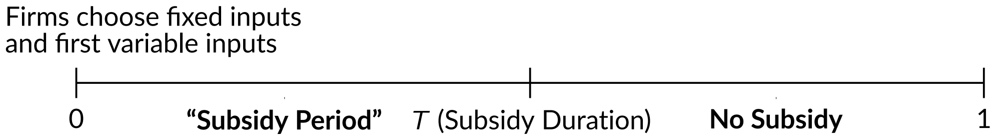

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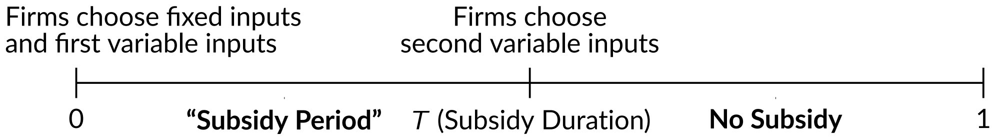

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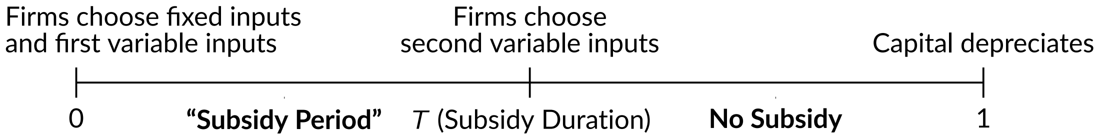
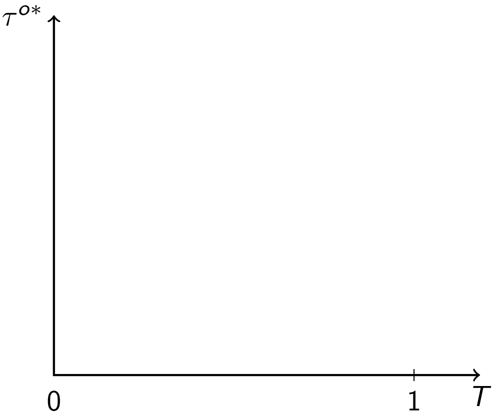
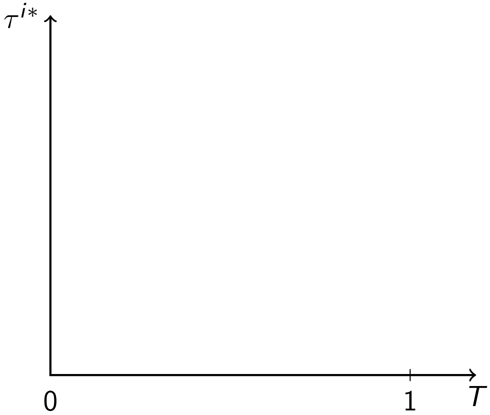


Time limits affect optimal subsidy calibrations and instruments





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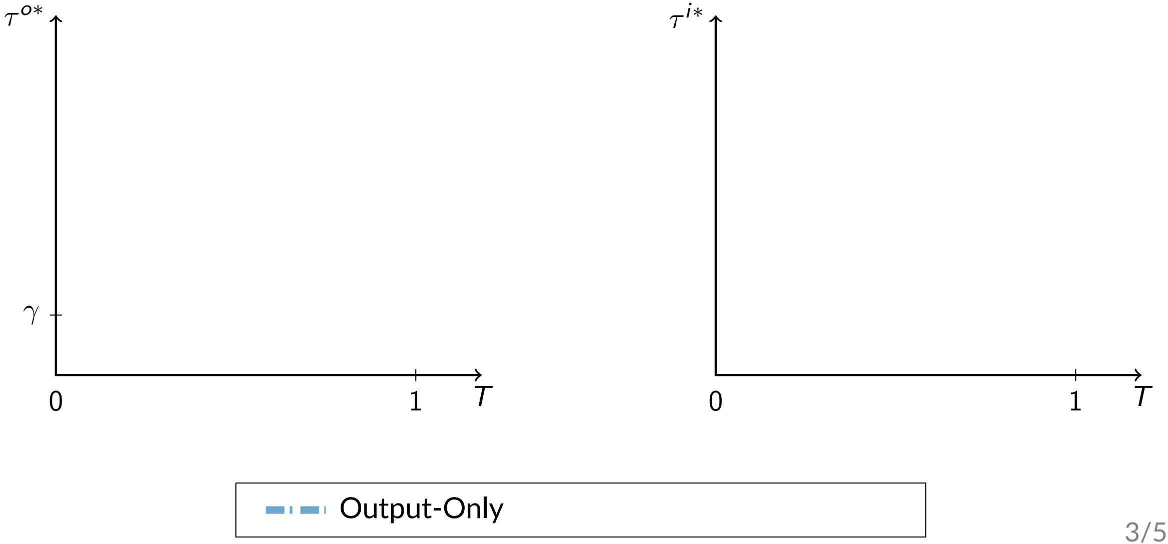

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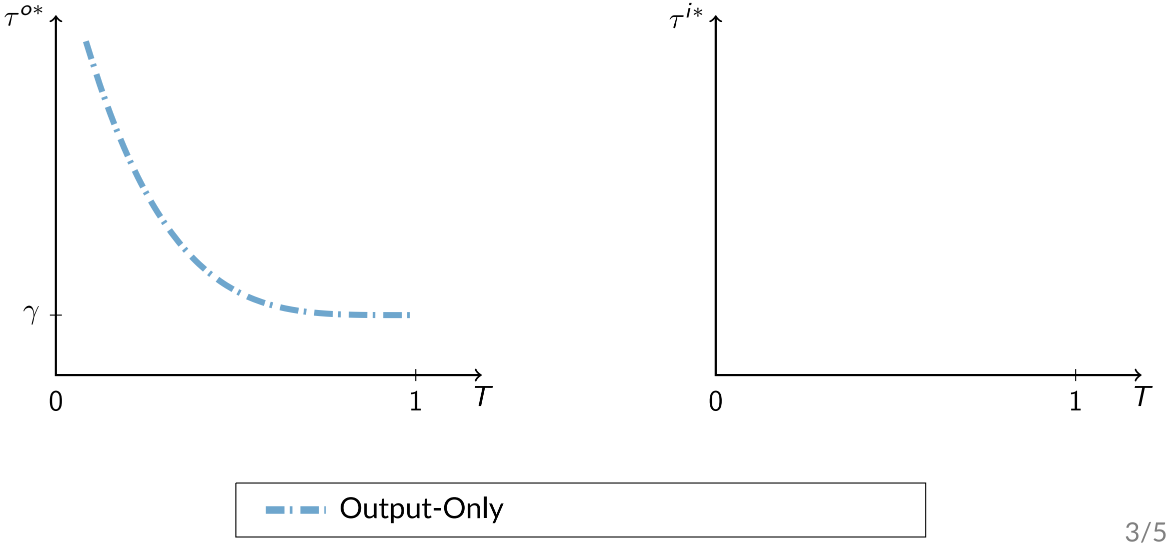

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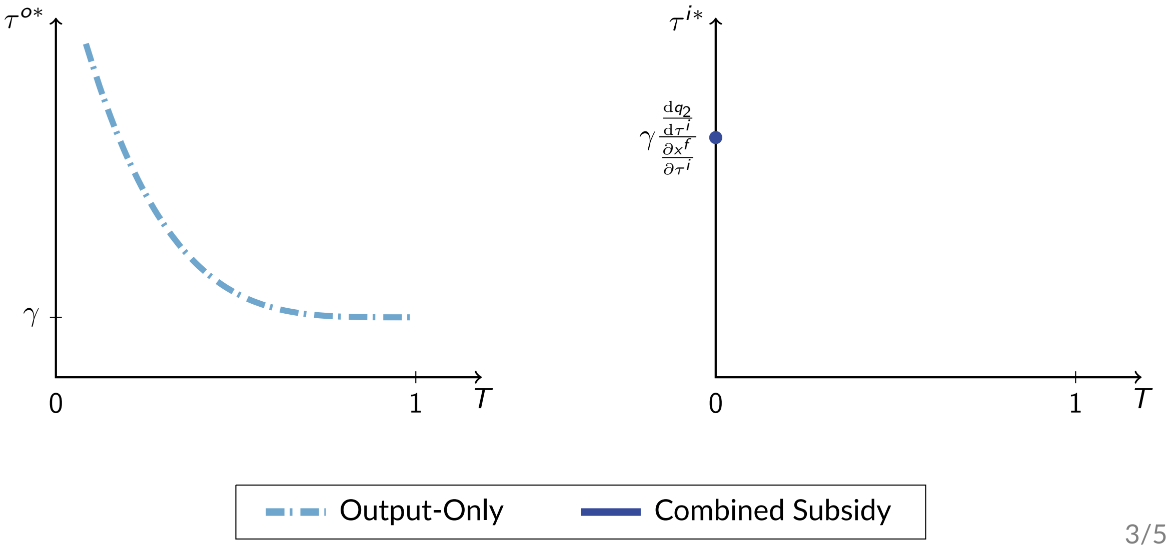

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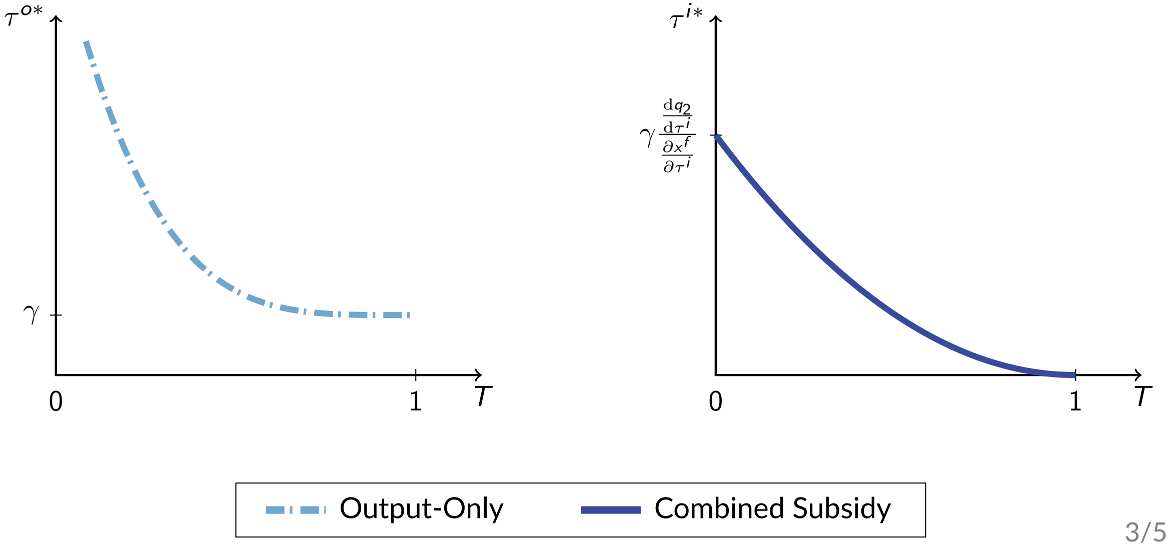

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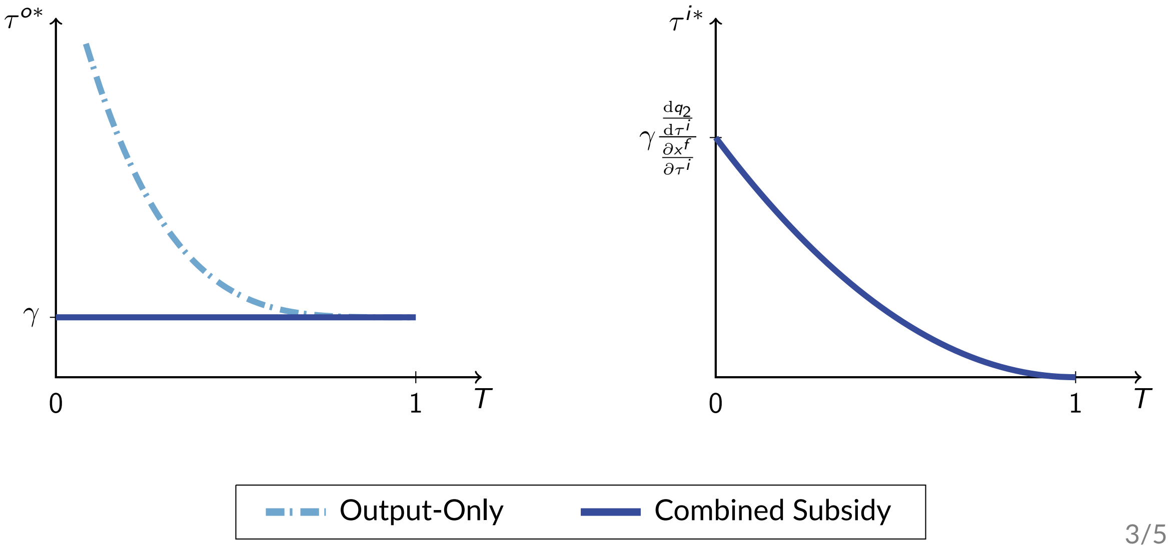

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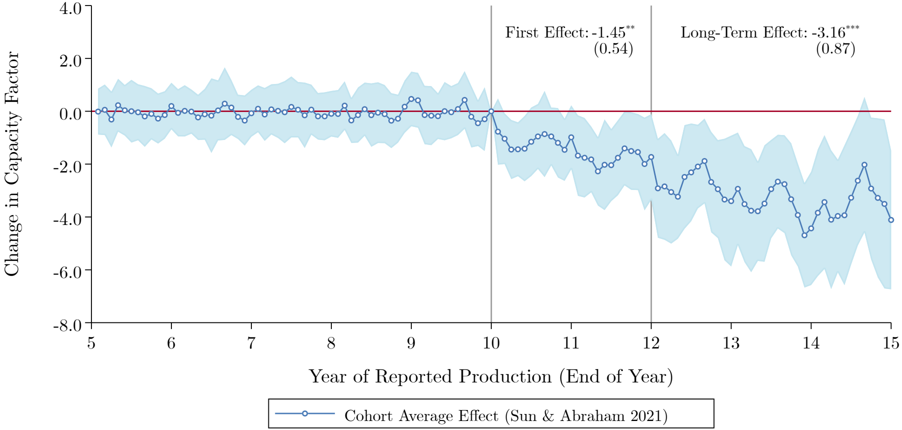

Economic review and takeaways

- Theoretical Takeaways
  - Time limits can trade off social costs of a policy against external benefits of production

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  - There is a noticeable decline in production (but a small elasticity)
  - The time limit has huge implications for future energy markets
  - ... and for policies aiming at an energy transition

Thank You!

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Appendix

2021

Instructions for Form 8835

Department of the Treasury
Internal Revenue Service

Renewable Electricity, Refined Coal, and Indian Coal Production Credit

Purpose of Form

Use Form 8835 to claim the renewable electricity, refined coal, and Indian coal production credit. The credit is allowed only for the sale of electricity, refined coal, or Indian coal produced in the United States or U.S. possessions from qualified energy resources at a qualified facility (see *Definitions*, later).

How To Figure the Credit

Generally, the credit for electricity, refined coal, and Indian coal produced from qualified energy resources at a qualified facility during the credit period (see *Definitions*, later) is:

- 1.5 cents per kilowatt-hour (kWh) for the sale of electricity produced by you;
- 1/2 of 1.5 cents for open-loop biomass, landfill gas, trash, hydropower, and marine and hydrokinetic renewable facilities; or
- $4.375 per ton for the sale of refined coal produced.
- $2 per ton for the sale of Indian coal produced.

Credit Period

Eligible electricity production activity:	Credit period for facilities placed in service after August 8, 2005 (years from placed-in-service date):
Wind	10
Closed-loop biomass	10
Open-loop biomass (including agricultural livestock waste nutrient facilities)	10
Geothermal	10
Municipal solid waste (including landfill gas facilities and trash combustion facilities)	10
Qualified hydropower	10
Marine and hydrokinetic	10
Indian coal	16[1]

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Global examples of output subsidies with time limits

- Policies in the United States:
  - Advanced Manufacturing Production Tax Credit—7 years
  - Renewable Energy Production Tax Credit—10 years per firm
  - Clean Vehicle Credit—10 years (with quotas)

- Policies in China:
  - Renewable Energy Tax Cut—6 years
  - Current Market Price Support for Oil Seeds—1 year

- Other examples
  - German Feed-in Tariffs—20 years
  - Canadian Dairy Price Support—1 year

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Firms Problem & Solution

Firm's problem:

$$\max_{x,v_1,v_2} \pi(x, v_1, v_2; \tau^i, \tau^o, T) = T[q(x, v_1)(1-\tau^o) - mv_1]$$
$$+ (1-T)[q(x, v_2) - mv_2] - cx(1+\tau^i)$$

Solution:

$$q_v(x^f, v_1^f)(1+\tau^o) = m$$
$$q_v(x^f, v_2^f) = m$$
$$Tq_x(x^f, v_1^f) + (1-T)q_x(x^f, v_2^f) + T\tau^o q_x(x_1^f, v_1^f) = c(1-\tau^i)$$

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Continuous time

Firm's problem:

$$\max_{x, v_t} \int_0^T \exp\{-\beta t\}\Big[q(x, v_t)(1-\tau_o) - m v_t\Big] dt + \int_T^1 \exp\{-\beta t\}\Big[q(x, v_t) - m v_t\Big] dt - cx(1+\tau_i)$$

The optimal τ_o and τ_i are

$$\tau_i^* = -\frac{\gamma(1-\tilde{T})\frac{\mathrm{d}q}{\mathrm{d}\tau_i}}{\frac{\partial x^f}{\partial \tau_i}} \quad (1)$$

$$\tau_o^* = -\gamma \quad (2)$$

where $\tilde{T} = \frac{1-\exp\{-\beta T\}}{1-\exp\{-\beta\}}$
and $\phi'(\tilde{T}^*) = -\gamma \Delta q$

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Variable input subsidy

Firm's problem:

$$\pi(x, v_1, v_2; \theta) = T\left[(1+\tau^o)q(x, v_1) - (m-\tau^n)v_1\right] + (1-T)\left[q(x, v_2) - (m-\tau^n)v_2\right] - (c-\tau^i)x$$

The optimal τ^o and τ^i and τ^n *are*

$$\tau^{i*} = (1-\tilde{T})\frac{\gamma\frac{\mathrm{d}\boldsymbol{q}}{\mathrm{d}\tau_i}}{\frac{\partial x^f}{\partial \tau_i}} \quad (3)$$

$$\tau^{o*} = \gamma \quad (4)$$

$$\tau^{n*} = 0 \quad (5)$$

and $\phi'(T^*) = -\gamma\Delta q$

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Government Problem

Optimal Mixed Subsidy

$$\max_{\tau^i,\tau^o,T} \Pi(x^f, v_1^f, v_2^f) + \underbrace{\gamma\left[Tq(x^f, v_1^f) + (1-T)q(x^f, v_2^f)\right]}_{\text{Externality Benefit}} + \underbrace{\left[cx^f\tau^i + T\tau^o q(x^f, v_1^f)\right]}_{\text{Government Revenue}} + \phi(T)$$

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Assumption 1b

- **Interior Solution**: $q(x, v)$ is increasing in both arguments with decreasing returns such that there exists an interior solution (x^f, v_1^f, v_2^f)

- **Implicit Function Theorem**: the firm choices (x^f, v_1^f, v_2^f) are implicit functions of θ with continuously differentiable first order conditions that produce a matrix $F = (f_x, f_{v_1}, f_{v_2}) = 0$ with a non-singular Jacobian with respect to x and v_t

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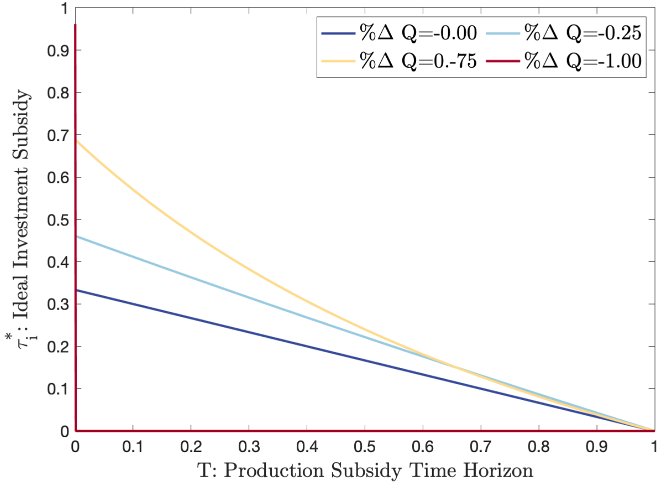
Optimal Subsidy Values Depend on the Duration



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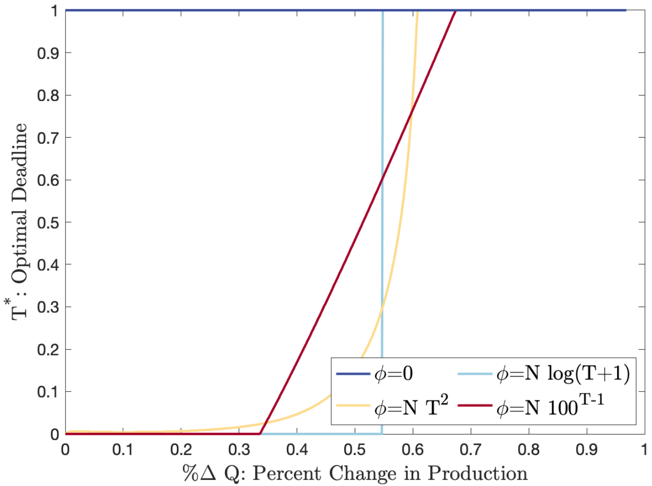
Optimal subsidy duration depends on change in production



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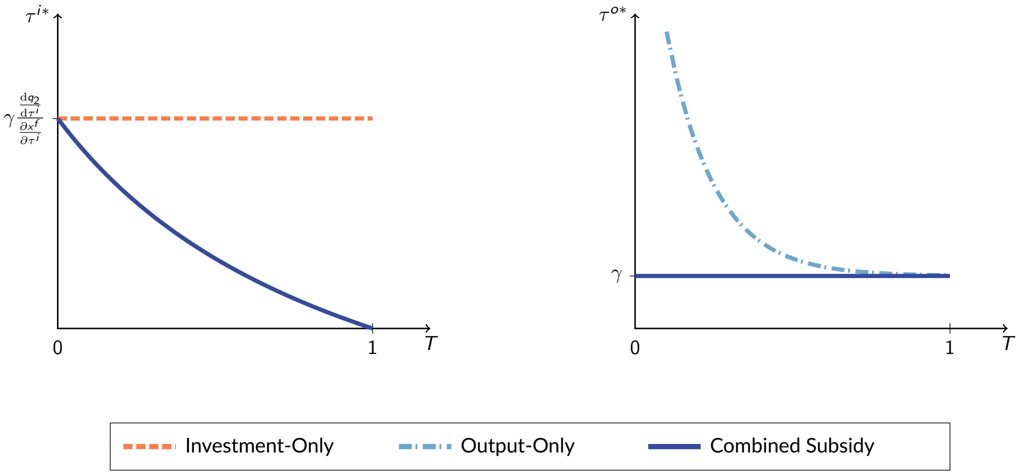
Comparing individual and combined policies



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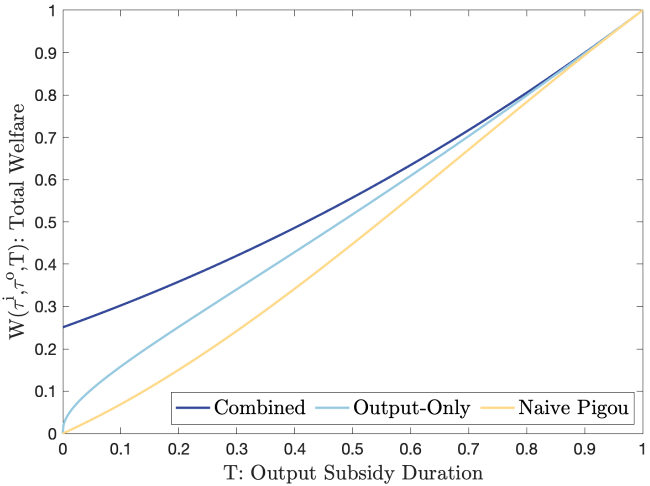
Naive policies forego large welfare gains (high ν-share)



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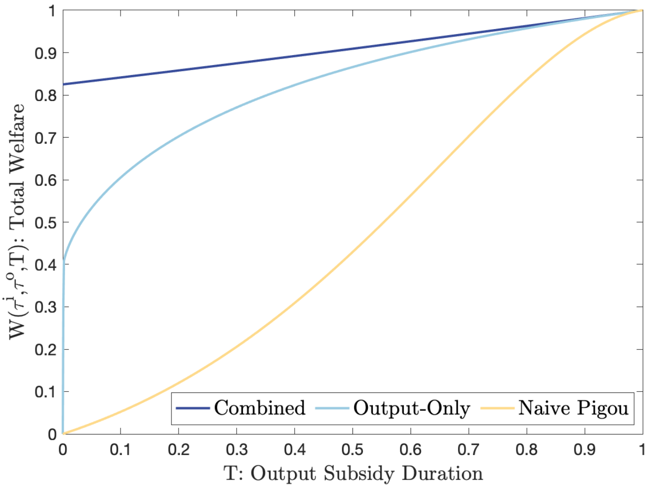

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Calibration details

- γ = Social Cost of Carbon + Avoided Emissions from Wind Energy
  - For the Social Cost of Carbon we use $51 per tonne from the Interagency Working Group on the Social Cost of Carbon (possibly a low estimate)
  - EPA's Avoided Emissions and Generation Tool estimates 1 MWh of onshore wind reduces CO_2 by 0.62 tonnes (1385 lbs).

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Only production margin shows changes

Panel A: Main Effects	Capacity Factor	Net Generation (MWh)	Exit: $\mathbb{1}$(Net Generation $= 0$)
Overall Effect	-2.32	-1072	0.00
	(0.67)	(388)	(0.01)
Short-Term (Years 11-12)	-1.45	-733	0.00
	(0.54)	(352)	(0.00)
Long-Term (Years 13-15)	-3.16	-1405	0.00
	(0.87)	(492)	(0.01)
Average in Year 10	31.3	16,858	0.02

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Heterogeneity by Vintage

Panel B: Heterogeneity by Vintage	2002-2006	2007-2008	2009-2010
Short-Term (Years 11-12)	-1.63	-0.54	-1.20
	(1.12)	(0.61)	(0.63)
Average in Year 10	32.4	32.0	29.1

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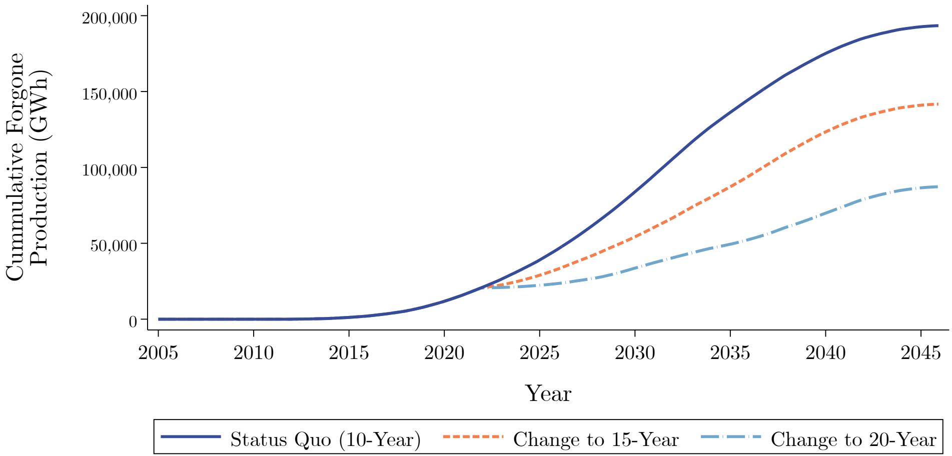
Prices and Placebo tests

Panel C: Effect Heterogeneity	1603 Firms (Placebo)	Low Price	High Price
Overall Effect	-	-2.37	-2.32
		(1.03)	(0.51)
Short-Term (Years 11-12)	-0.33	-1.97	-1.09
	(0.44)	(0.87)	(0.40)
Long-Term (Years 13-15)	-	-2.73	-3.65
		(1.23)	(0.77)
Average in Year 10	28.2	32.0	30.7

Forgone wind energy production



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Inverse optimum for marginal social costs of subsidy duration

- The marginal administrative costs needed to rationalizing current policy mus satisfy:

$$\phi'(T^*) = -\gamma \Delta q$$

  - We calibrate γ = $31/MWh

- Average change in production is 800 MWh/month
  - Implies marginal administrative costs at least $24,000 per firm per year (since $\phi()$ is convex)
  - If this is larger than seems reasonable, it's optimal to expand eligibility

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Inverse Optimum Table

Panel A: Social Cost of Raising Revenue		Change in Production:				
Reference Policy	Social Value of 1 MWh	$\%\Delta Q$ = 2.5%	$\%\Delta Q$ = 4.5%	$\%\Delta Q$ = 6.5%	$\%\Delta Q$ = 8.5%	$\%\Delta Q$ = 10.5%
Trump	$ 1.00	0.84	0.76	0.69	0.64	0.60
PTC	$ 25.00	1.00	1.00	1.00	1.00	1.00
	$ 30.00	1.03	1.05	1.06	1.08	1.08
EPA	$ 35.00	1.07	1.10	1.13	1.15	1.17
Min CL (2019)	$ 40.00	1.10	1.15	1.19	1.23	1.25
	$ 45.00	1.13	1.20	1.26	1.30	1.33
	$ 50.00	1.16	1.25	1.32	1.38	1.42
	$ 55.00	1.20	1.30	1.39	1.45	1.50
Max CL (2019)	$ 70.00	1.30	1.46	1.58	1.68	1.75
	$ 85.00	1.39	1.61	1.77	1.90	2.00
	$ 100.00	1.49	1.76	1.96	2.13	2.25

Panel B: Social Cost Extending Deadline		Change in Production				
Reference Policy	Social Value of 1 MWh	$\%\Delta Q$ = 2.5%	$\%\Delta Q$ = 4.5%	$\%\Delta Q$ = 6.5%	$\%\Delta Q$ = 8.5%	$\%\Delta Q$ = 10.5%
Trump	$ 1.00	-2.40%	1.23%	11.47%	32.16%	68.15%
PTC	$ 25.00	0.41%	0.75%	1.08%	1.42%	1.76%
	$ 30.00	0.52%	0.94%	1.38%	1.83%	2.29%
EPA	$ 35.00	0.44%	0.84%	1.29%	1.79%	2.31%
Min CL (2019)	$ 40.00	0.19%	0.44%	0.77%	1.20%	1.69%
	$ 45.00	-0.19%	-0.27%	-0.23%	-0.07%	0.22%
	$ 50.00	-0.71%	-1.30%	-1.80%	-2.18%	-2.40%
	$ 55.00	-1.35%	-2.66%	-4.02%	-5.37%	-6.62%
Max CL (2019)	$ 70.00	-3.92%	-8.93%	-15.85%	-25.68%	-39.84%
	$ 85.00	-7.35%	-19.01%	-40.19%	-87.40%	-259.53%
	$ 100.00	-11.51%	-33.84%	-90.64%	-451.70%	Negative Welfare

References